# 2009 Roads and Bridges Conference

## GW - 08

## Advanced Earthworks

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# Module Overview

In this module we will review the GEOPAK Earthwork application and how to compute various materials and material classifications. This includes setting up the application with information necessary to identify materials on proposed cross sections.

# Modules Objectives

Upon completion of this module you will be able to:

- Create soil types
- Specify material classifications
- Compute complex earthwork

# Introductory Knowledge

Before beginning this module let's define what you already know.

## Questions

1. Project information about cross sections is defined in what application?
2. GEOPAK identifies cross sections in a MicroStation file by what attribute?
3. A cross section cell contains what five pieces of information?

## Answers

1. Project information about cross sections is defined in what application?

**Project information about cross sections is defined in the Working Alignment Definition.**

2. GEOPAK identifies cross sections in a MicroStation file by what attribute?

**GEOPAK identifies cross sections by the cross section cell.**

3. A cross section cell contains what five pieces of information?

**Cross section cells contain: baseline, station, elevation, width and planimetric location.**

GEOPAK computes earthwork by reading and interpreting the MicroStation design files containing proposed and existing ground cross sections. This approach affords the user maximum flexibility in that it is irrelevant whether the cross section elements were created entirely by GEOPAK or were created or modified using generic MicroStation commands.

The only two elements needed to run earthwork are:

MicroStation design file containing proposed cross sections and existing ground lines.

GEOPAK job number and baseline. (Only required if the baseline has station equations or if centroid adjustment is requested).

GEOPAK computes end areas and volumes solely from the MicroStation elements representing existing ground, suitable and unsuitable substrata layers, proposed finish grade and proposed undercut layers in a single processing. Any alterations to the cross sections made via generic MicroStation commands are reflected in the earthwork quantities.

These graphical cross sections can be very simple to compute only cut/fill quantities or very complex cross sections including several types of unsuitable or removable materials, and several fill material types. There is no limit to the number of existing or proposed soil types.

In some projects, it is necessary to remove existing materials such as rubble, concrete or bituminous pavement, or topsoil and have specific quantities for each. This can be accomplished easily with GEOPAK.

As soon as the finished grade of proposed cross sections is complete, an initial earthwork run can be processed. As the design is refined, a more precise report can be produced reflecting any modifications made to the cross section design file. Once the proposed cross sections have been drawn (including subsurface features), and existing removals and excavation limits have been added, then the final earthwork can be computed. An optional feature to place the earthwork quantities during the cross section sheet development is also reviewed.

After earthwork is computed, GEOPAK offers a series of interactive tools to review and manipulate earthwork volumes. These tools include the capability to draw the mass diagram, adjust the multiplication factors (shrink/swell factors) for varying stations, set force balance points and add/subtract volumes.

The following lists some of the features inherent in GEOPAK earthwork: (Note that these features are available in a single processing, multiple runs are not necessary.)

Unlimited material types.

Unlimited layers of existing substrata.

Unlimited layers of proposed undercuts.

The removal of topsoil or any other material along with the material redeployment on side slopes.

Unsuitable material removal between excavation limits. The software will also account for suitable material that lies above the unsuitable material and must be removed in order to access the unsuitable material.

Separate expansion/shrinkage factors can be defined for each material type.

Within each material type, separate expansion and shrinkage factors can be specified for the common and subgrade excavation, subsoil excavation and fill classifications.

Expansion/shrinkage factors can be varied between stations.

Balance point stations are noted and the volumes summarized.

Add/Subtract volumes.

Skip areas.

Centroid adjustments for circumstances where the bulk of the end areas are predominantly and consistently to one side of the baseline or the other.

GEOPAK is extremely flexible when computing earthwork, utilizing several types of excavation and fill, many functional classifications, numerous material types, (known as soil types), and different shrink/expansion factors.

In order to tell the software how to compute earthwork, a thorough understanding of these concepts is mandatory.

**Excavation Types**

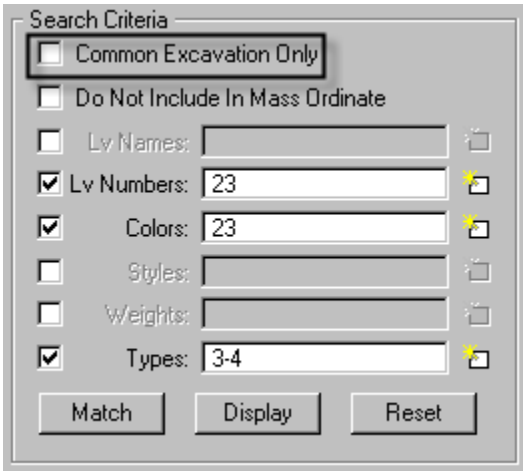
Several types of excavation are supported in GEOPAK. These include:

**Common excavation** - excavation volumes that are not backfilled with an earthwork material. This includes the excavation required for cut sections as well as for pavement thickness, shoulder thickness, etc.

**Subgrade excavation** - excavation volumes that are backfilled with an earthwork material.

**Subsoil excavation** - excavation required to remove unsuitable material down to the bottom of the proposed template.

These are not specified by the user but are determined by the software. However, there are cases where material is placed in subgrade excavation when it should be classified as common. An example is a layer of topsoil added to the proposed side slopes in a cut section. In order to "override" the software and force the material into common excavation, the keywords **common excavation only** should be added after proposed undercut.



## Embankment Types

In addition to the excavation types, GEOPAK determines where fill material is required. The user does not specify where embankment is required as GEOPAK determines it from the graphic elements in the MicroStation cross-section design file. GEOPAK does not have various types of fill similar to the various types of excavation, however, the user does have control of the various types of material used for embankment. Let's look at the basic requirements for earthwork.

## Basic Functional Classes

**Functional classes** identify the function or purpose of the cross section element. In order to compute the most basic earthwork, two functional classes are required. They are:

Proposed Finished Grade

Existing Ground

**Functional classes** are determined by the designer. With each functional class, additional project-specific information must be supplied in order for GEOPAK to compute the quantities. This information required includes:

Soil Type

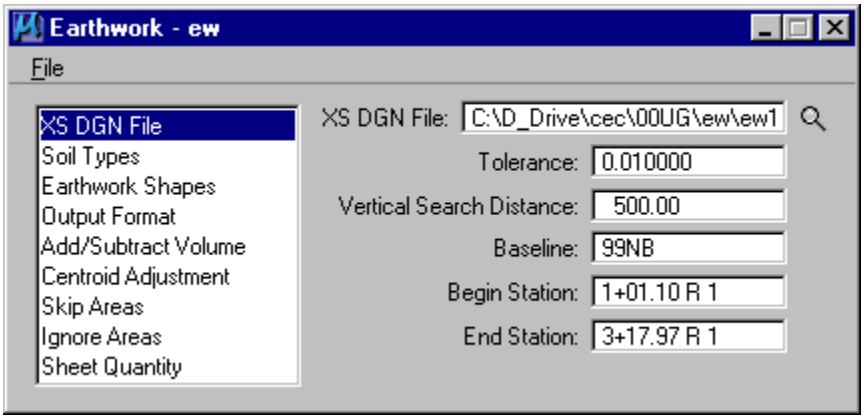
Element Symbology of the Material

Shrink/Swell Factors

## Project Manager

### XS Dgn File

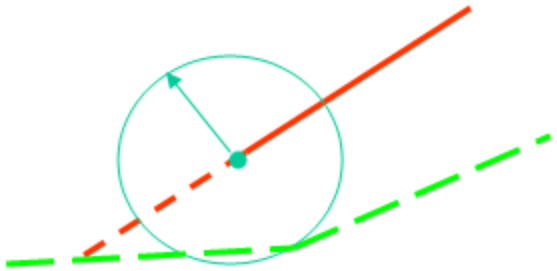
When the XS DGN File option is selected, the dialog changes as depicted below.




Fields in the dialog above are detailed in the table below.

**XS DGN File** MicroStation 2D file containing cross-sections (and xscell) to be utilized for earthwork computations.

**Tolerance** The tolerance can be specified if different from the default. GEOPAK utilizes the tolerance as the radius of a circle as depicted in the graphic below. If the lines intersect within the circle, the software will consider the lines intersecting. GEOPAK supports **vertical** ties at the outside limits of construction as well as any interior locations.



**Vertical Search Distance** The earthwork component of GEOPAK calculates earthwork quantities from the MicroStation elements present for each cross section independent of whether these cross section elements were drawn by GEOPAK or drawn with generic MicroStation commands. For each cross section, GEOPAK searches for candidate cross section elements within a certain vertical range from the cross section cell. In order to ensure that each element associated with a given cross section is found, GEOPAK searches for and analyzes elements vertically within 250 master units above and below the horizontal portion of the cross section cell. Therefore, should any cross section include terrain relief in excess of 250 feet, the Vertical Search Distance must be utilized. As a rule, the vertical search distance is usually 3/4 of the user-defined Distance Between Cross section Cells.

**Baseline** Baseline utilized to create the cross section cells.

**Beg Station** Defaults to the lowest numbered station in the file. However, this can be changed if only a selected station range for computation is desired.

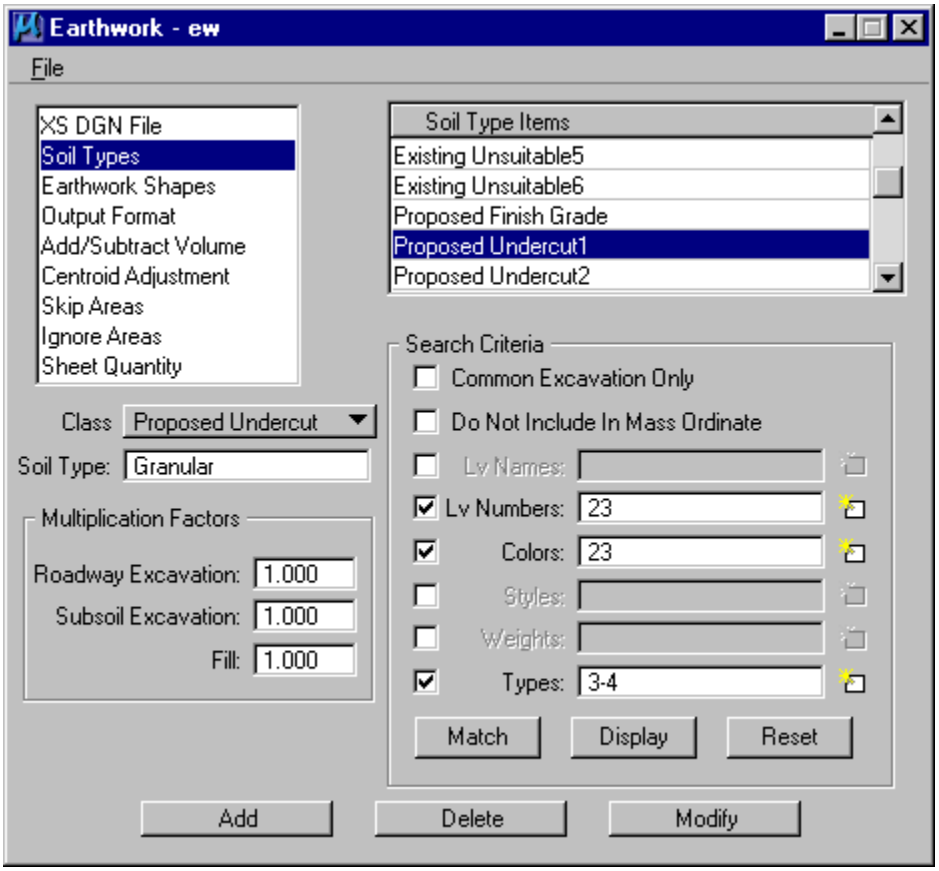
**Note:** Regions must be included if station equations are present in the Baseline.

**End Station** Defaults to the highest numbered station in the file. However, this can be changed if only a selected station range for computation is desired.

**Note:** Regions must be included if station equations are present in the Baseline.

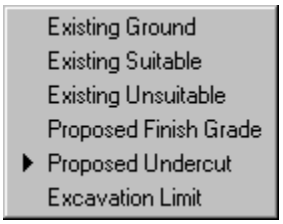
### Soil Types

When the Soil Types option is selected, the dialog changes as depicted below.




### Class

Several classes are supported including:




**Proposed Finish Grade**

The proposed finish grade includes the top of proposed pavement, curb and gutter, top of proposed topsoil, top of proposed ditches, etc. The software must be able to ***contiguously*** draw from the centerline to the touchdown point using these levels. Note these would be the levels used for producing slope stakes or construction limits and therefore, does not include any subsurface elements.

The soil type specified with the proposed finish grade is important, as it is the default fill material. Only one default material may be specified. This material is utilized by the software in areas where the proposed finish grade is above the existing ground.

**Existing Ground**

Existing ground must also be specified. Its associated material type determines the soil type underneath the lowest substrata line. The existing ground must be contiguous between the proposed tie down points using these levels. Note these would be the existing ground levels used for producing slope stakes or construction limits and therefore, do not include any subsurface elements.

The soil type specified with the existing ground is important as it is the default excavation material. Only one default cut material may be specified. This material is computed by the software in areas where the proposed finish grade is below the existing ground.

**Proposed Undercut**

Proposed undercuts are used to define any proposed component which is not part of the finished grade. This includes undercuts, proposed topsoil placement, or aggregate quantities. Although the proposed undercut is used to define undercuts or subcuts, it is important to remember that the soil type is not the material being removed, but what the area will be backfilled with. The material being removed is computed in the default excavation unless it is an existing suitable or unsuitable material. The multiplication factor is again optional, and defaults to one. The roadway and subsoil excavation factors may also be utilized. The element symbology must specify a unique layer of material for each soil type and all proposed undercuts must tie to another proposed undercut or proposed finish grade, not to existing ground. Let's look at an example with multiple proposed undercuts.

**Existing Suitable**

**Existing Unsuitable**

Existing suitable and unsuitable materials play an important role in GEOPAK earthwork as they provide the mechanism to obtain removal quantities. In-place removals can include a variety of materials. Some can be defined as precise closed shapes, such as in-place concrete pavement removals, while others are variable sized shapes, such as variable depth bituminous pavement, while others are layers of materials such as muck, rock or topsoil.

**Excavation Limit (no soil type needed)**

Excavation limits are short lines drawn onto cross sections to tell the software where to stop removing existing unsuitable or suitable material. They have no direct correlation to proposed features, except that the removals normally end at the outside edge of proposed construction.

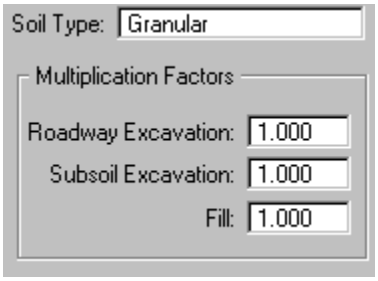
Excavation limits are required whenever existing suitable or unsuitable classifications are utilized and the removal area is ***not*** a closed area completely within a cut area.

All classes (except as noted) require a Soil Type and Search Criteria.

> **Note:** The Soil Type is extremely important as it dictates what materials are re-used and which materials are not. If the soil types for any two functional classifications are identical, GEOPAK will re-use the excavation material in places where embankment is required.

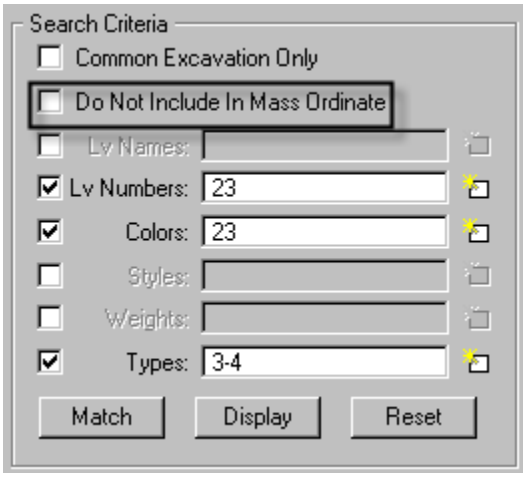
**Multiplication Factors and Mass Ordinate**

The multiplication factors (also known as shrink/swell factors) default to 1.0 if not specified. However they can be specified for each material type, and different factors can be used for excavation than for fill. When using these stratified factors, if any of the three is not specified, GEOPAK defaults the missing factor to 1.



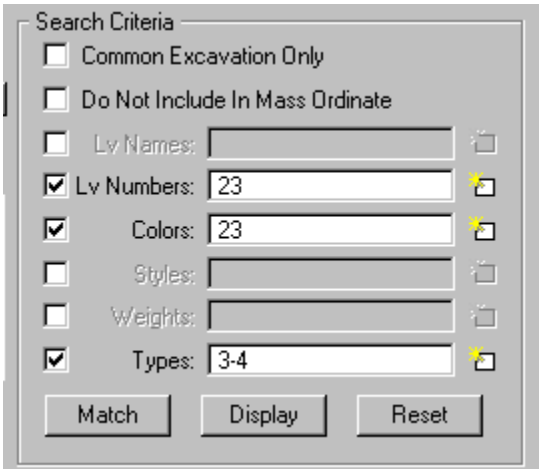

**Note:** If the material type is used in several classifications, (such as topsoil in both existing unsuitable and proposed undercut), the factors must be identical in each classification.

In some cases, it is desirable to omit some materials from the mass ordinate. Multiplication factor = 0 is supported in GEOPAK, and will keep the material out of the mass ordinate for existing suitables and unsuitables, which accrue their own mass ordinates. However, the easiest method for Proposed Undercuts is the activation of the **Do Not Include in Mass Ordinate** toggle located at the top of the Search Criteria group box.




**Search Criteria**

Element symbology is extremely important as it tells the software which function each element has. Level, color, weight and line style may be utilized, although not all parameters are necessary, only enough to give uniqueness to the function. Note the type ***must*** be line or line_string. Arcs, curves, curve_strings, and complex strings are ***not*** acceptable element types.



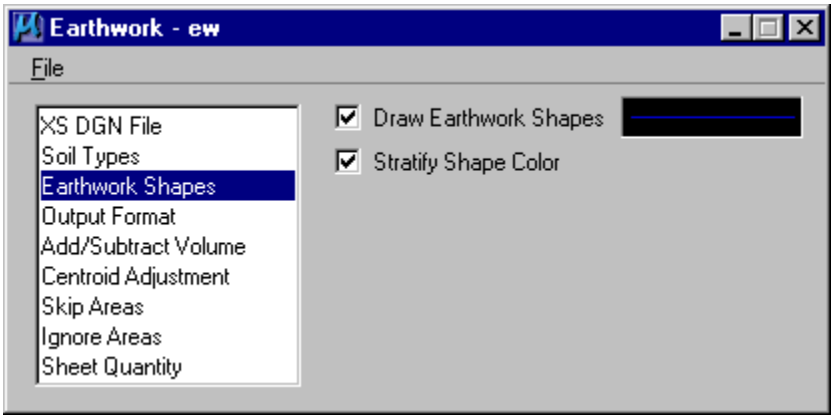

When specifying the element symbology, care must be given to avoid including elements which are not part of the finished grade. To avoid this problem, careful assignment of element attributes when doing proposed cross sections is necessary.

**Steps for adding material layers**

1. Select the Class, which determines the rest of the dialog settings. For example, select Existing Ground.
2. Key in the Soil Type, utilizing **NO** spaces between characters.
3. Set Multiplication Factors if a value other than one is desired.
4. Define the desired element symbology, utilized as many parameters as required to provide uniqueness to the specified material. Note the display in Criteria Status.
5. Press the Add button at the bottom of the dialog. The item is added to the Soil Type Items list box.

**EW Shapes**

When the EW Shapes option is selected, the dialog dynamically changes as depicted below.




When the Draw Earthwork Shapes toggle is active, the earthwork shapes are drawn with color fill attributes. When the Fill toggle is active on the View Attributes dialog, color filled complex shapes are displayed.

The shapes either can be drawn in a single color or various colors can be assigned to various types of cut and fill. When the Stratify Shape Color is not active, the actual color corresponds to the color defined for the plot parameters within the dialog. In this instance, every shape would be filled with the color assigned to color 1.

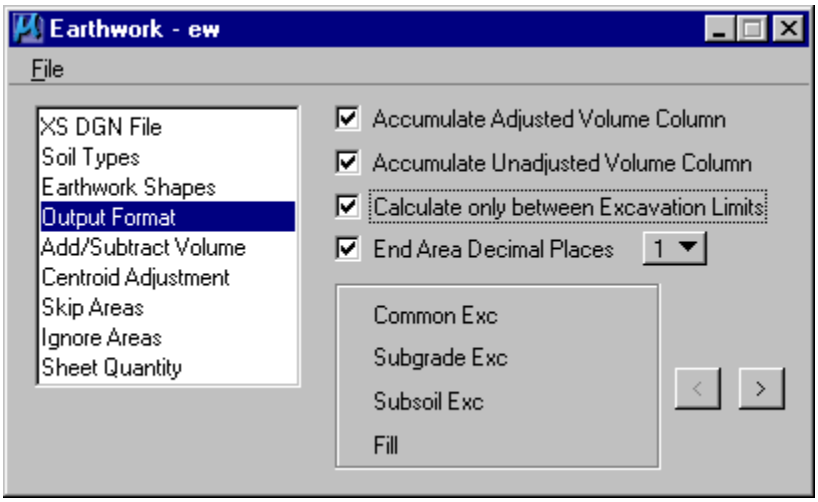
Variations in color between various cut and fill options are achieved with the Stratify Shape Color toggle active. Utilizing the order within the Soils Type dialog, GEOPAK assigns (in ascending numerical order) each material type two colors, one for cut and one for fill.

Color assignments initialize at zero, regardless of the color listed in the plot parameters of the write earthwork shapes. However, the specified level is utilized for drawing the complex shapes.

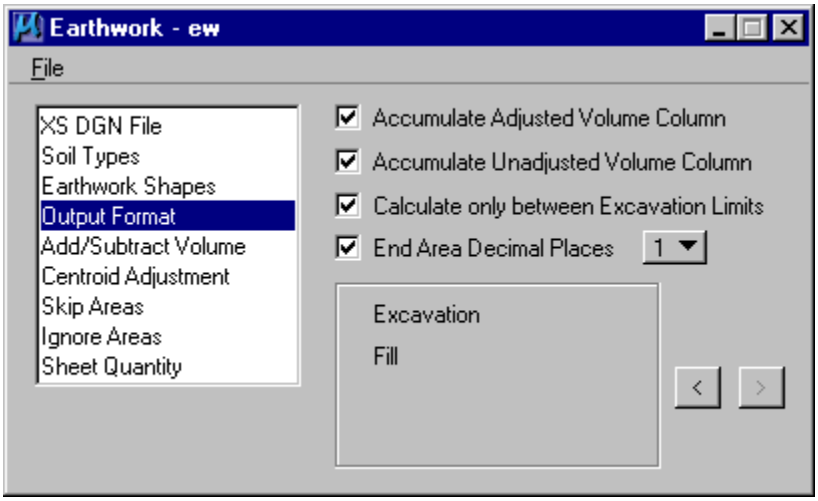
Combination areas, those which involve both cut and backfilling utilize the fill color, and ignore the cut color.

### Output Format

Three classifications of excavation volumes are listed on standard GEOPAK earthwork outputs: common, subgrade, and subsoil. In certain design instances, the designer does not require these distinctions. Hence, the Output Format dialog (as depicted below) can be utilized to combine various quantities.




With this command, any combination of the three classifications of excavation volumes can be formulated. For example, if the user desires to combine all three into an earthwork listing of simply cut and fill, press the < or > arrows until the desired option is displayed.




**Options include:**

Common Exc, Subgrade Exc, Subsoil Exc, and Fill

Excavation (Common and Subgrade), Subsoil Exc, and Fill

Excavation (Common and Subsoil), Subgrade Exc, and Fill

Excavation (Subgrade and Subsoil), Common Exc, and Fill

Excavation (all types) and Fill

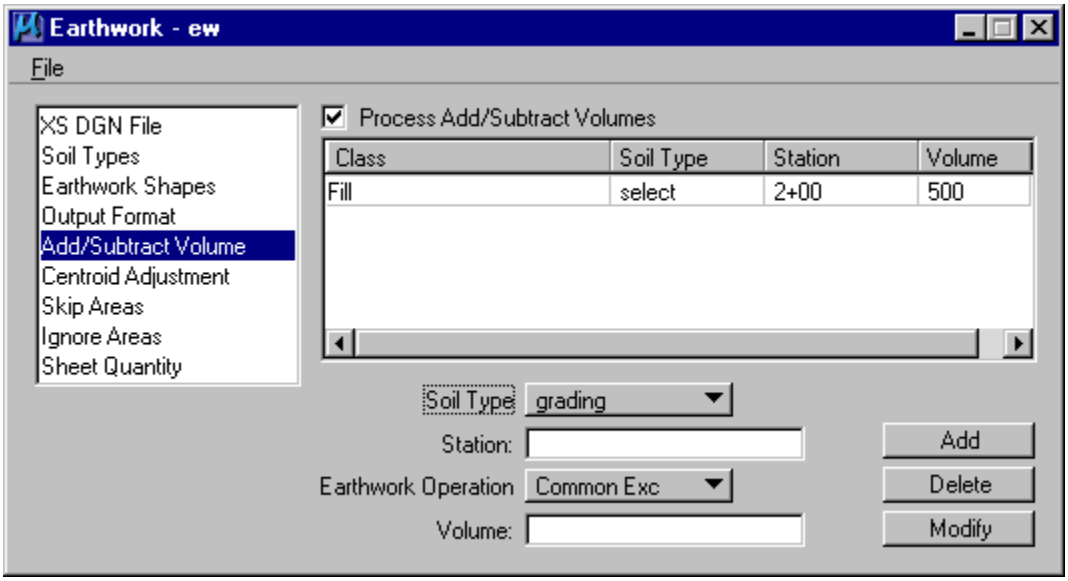
**Calculate Only Between Excavation Limits**

Another option within this dialog is Calculate Only Between Excavation Limits. In this case, the use of excavation limits is to demarcate earthwork processing. This is extremely useful in projects where earthwork is staged or separate quantities for each roadway in a multiple alignment is necessary. When the toggle is activated, **ALL** earthwork calculations are limited to within user-defined excavation limits, not just existing removals.

**Add / Sub Volumes**

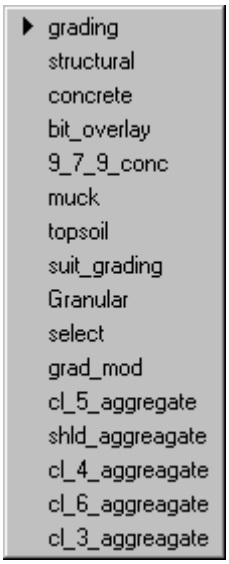
Volume adjustments can be specified at project locations where material surpluses or deficits are encountered outside that which can be described via the cross sections. Add/subtract volumes might be applied to driveway or borrow pit locations. Volume adjustments can be specific according to one of four classifications: common excavation, subgrade excavation, subsoil excavation and fill.

When the Add / Sub Volumes option is selected from the Earthwork list, the dialog dynamically changes as depicted below.

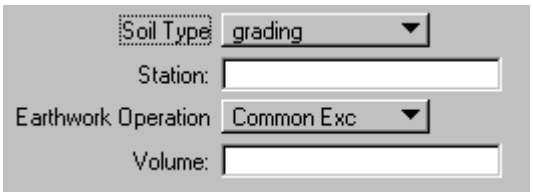



The Soil Type must comprise a character string that exactly matches the character string specified for the various earthwork functional classifications (e.g. existing ground, existing suitable material, existing unsuitable material, existing removable, proposed finish grade and proposed undercut.)

Therefore, it must be selected from the list, rather than a keyin field.



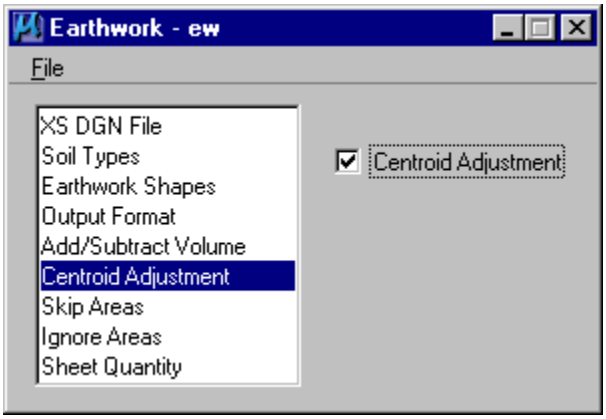

The station indicates the location at which volumes are added to or subtracted from the mass ordinates and does not necessarily have to be at a cross section station. However, it must be within the specified station range. Subtract volumes are included with a minus (-) sign in front of the quantity. The volume adjustment header and subsequent syntax must be repeated for each add/subtract location, soil type or volume quantity. For example, if there is a volume adjustment to the common excavation and fill volumes at a particular station, two volume adjustments are needed.




To populate the list box, select the Soil Type and type in the Station and Volume. If the baseline has station equations, the regions must be included. Select the EW Operation, then press the Add button. The data is added to the list box. To Modify data, highlight the line to be modified, which populates all fields. Change the desired value, then press the Modify button. The change is reflected in the list box. To delete a line, highlight the line to be deleted, then press the Delete button. The line is deleted from the list box. There is no limit to the number of defined add volumes.

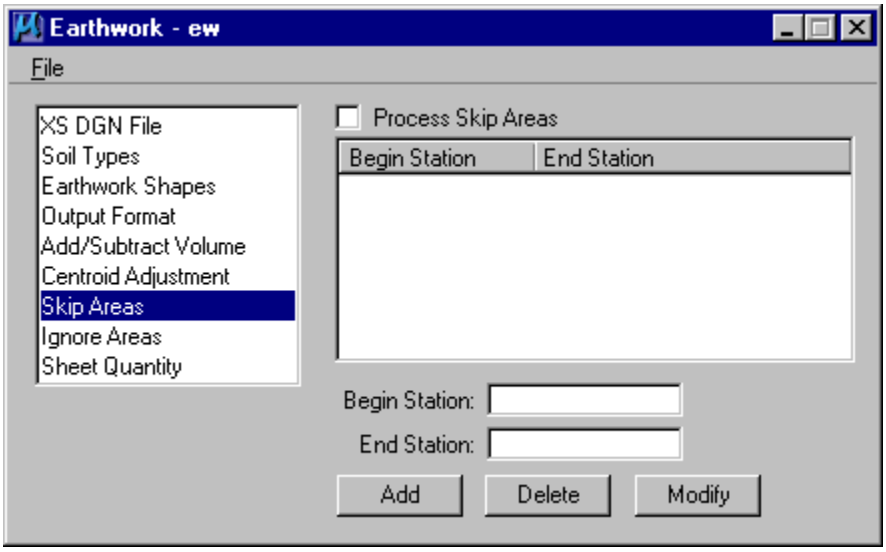
## Centroid Adjustment

Earthwork volumes are calculated by averaging end areas and then multiplying these averaged areas by the distance between two successive cross sections as measured along the baseline. If the bulk of the cross section areas are located predominantly to either the left or the right of the baseline, as in a detour, an error occurs in the volume calculations for all non-tangential portions of the baseline. This error can be negligible or substantial depending on the degree of baseline curvature as well as the degree to which cross section areas are offset about the baseline.



### Skip Area

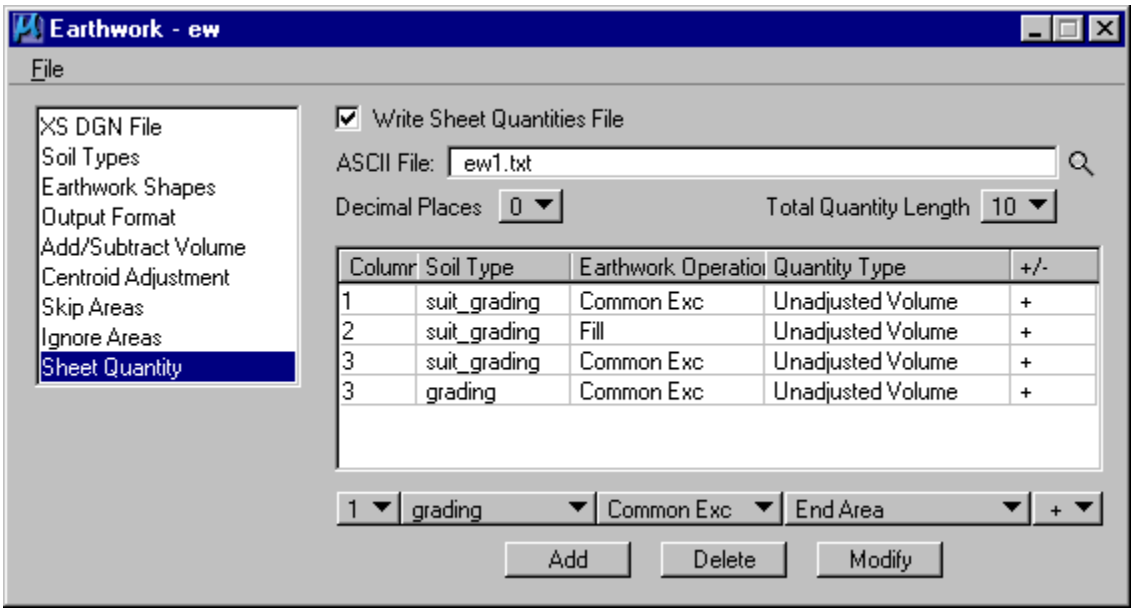
Skip areas are ranges of stations between which volume quantities are not calculated. End areas continue to be calculated for each cross section, but volume calculations are not performed between user specified station ranges. One area of application for skip areas would be bridge overpasses.




### Sheet Quantities

Earthwork quantities can be written directly onto cross sections sheets. A two step process is required. First, an ASCII text file is produced when calculating earthwork volumes. This ASCII text file contains the area and/or volume quantities that are to be written onto the cross section sheets. Second, the GEOPAK sheet layout utility reads this ASCII file and places the appropriate text onto the cross section sheets.

When the Sheet Quantities is selected, the dialog dynamically changes as depicted below.




Formulae are supported within GEOPAK enabling the user to add or subtract any calculation entity. These calculation entities are comprised of three components:

Soil Type: The selected material type for which quantities are to be calculated. The material type is represented by a text string that must match a text string representing a material type defined by the user in the earthwork input file.

Earthwork Operation: The second component must be either one of the following: common excavation, subgrade excavation, subsoil excavation or fill.

Quantity Type: This represents the actual quantity including: end area, adjusted volumes, unadjusted volumes and for mass ordinates.

In summary, the following procedure adds items to the list box.

1. Select the Column Number, Decimal Places, and Total Quantity Length.
2. Select the Soil Type.

**Note:** Only those Soil Types defined in the Earthwork – Soils Type dialog are available for use.

3. Next, select the Earthwork Operation and Quantity Type. If several quantities are to be added, the Plus operand is default. The Plus is also utilized for a single quantity entry. However, it must be changed to Minus if the quantity is to be subtracted.

4. Press the Add button. The data is now displayed in the list box.

5. To add another quantity, **do not** change the Column number. Complete the remainder of steps, then press the Add button.

**Note:** In the list box that each Column number may have multiple entries.

## Lab Exercise: Earthwork

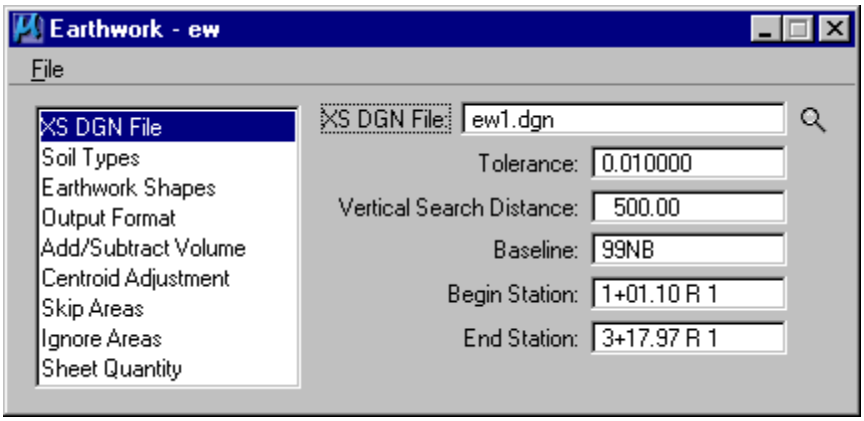
**1.** Access the MicroStation file **ew1.dgn**

**2.** Access **Project Manager** and the available project called **EW1**

**3.** Continue to the **Road** workflow dialog.

**4.** Access the **Earthwork** button and create a new **RUN** called **EW1**

5. Enter the following information into the first option of the dialog.




6. For the **Soil Types**, use the following input to define the various soil layers for earthwork computations.

**Proposed Undercut**

soil type = **GRANULAR**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 23

co = 23

**Proposed Undercut**

soil type = **GRADING**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 21

co = 23

**Proposed Undercut**

soil type = **SELECT**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 11-12

co = 11-12

**Proposed Undercut**

soil type = **GRAN_MOD**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 12

co = 31

**Proposed Undercut**

soil type = **CL_5_AGGREGATE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 26,55

co = 26,55

**Proposed Undercut**

soil type = **SHLD_AGGREGATE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 26,55

co = 3,32

**Proposed Undercut**

soil type = **CL_4_AGGREGATE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 55

co = 36

**Proposed Undercut**

soil type = **CL_6_AGGREGATE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 55

co = 36,55

**Proposed Undercut**

soil type = **CL_3_AGGREGATE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 54

co = 26

**Proposed Undercut**

soil type = **TOPSOIL**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 50

co = 50

**Proposed Undercut**

soil type = **MUCK**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 15,23,52,59

co = 23,59

**Proposed Undercut**

soil type = **COCNRETE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 30

co = 5

**Existing Ground Line**

soil type = **GRADING**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 2

**Existing Unsuitable Material**

soil type = **STRUCTURAL**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 19

co = 19

**Existing Unsuitable Material**

soil type = **CONCRETE**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 33

co = 19

**Existing Unsuitable Material**

soil type = **BIT_OVERLAY**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 33

co = 6

**Existing Unsuitable Material**

soil type = **9_7_9_CONC**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 36

co = 36

**Existing Unsuitable Material**

soil type = **MUCK**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 15

co = 24

**Existing Unsuitable Material**

soil type = **TOPSOIL**

roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

fill mult factor = 1.000000

type = line, line_string

lv = 13

co = 19

**Proposed Finished Grade**

soil type = **SUIT_GRADING**

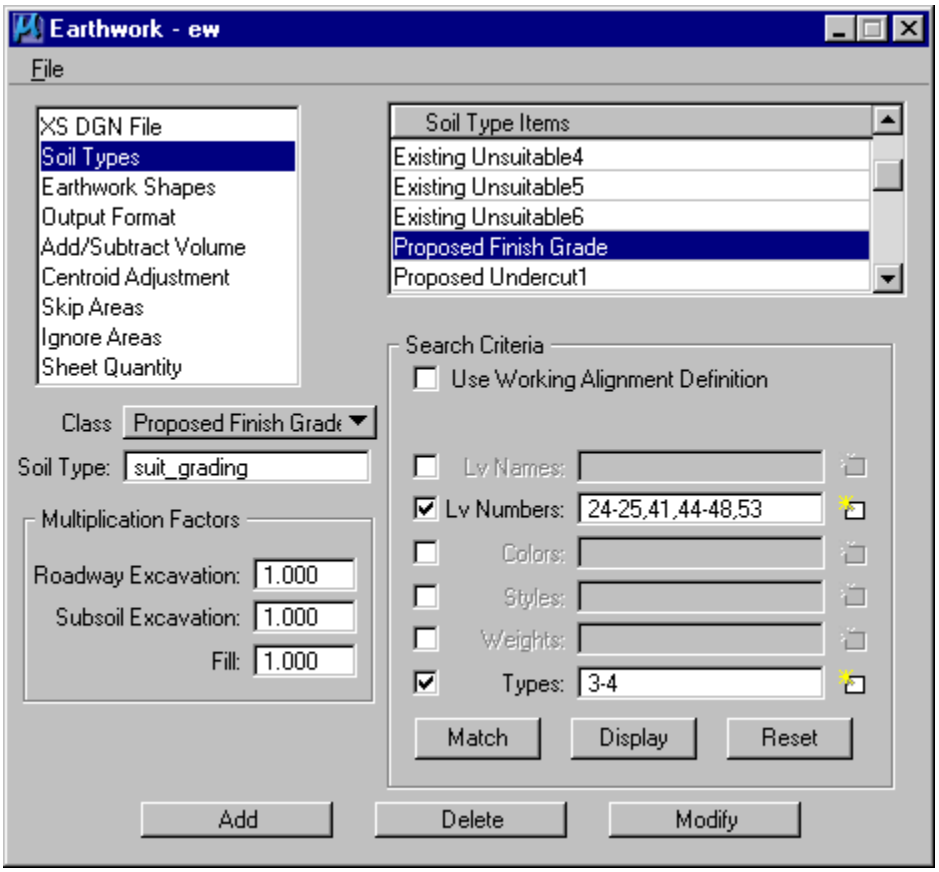
roadway exc mult factor = 1.000000

subsoil exc mult factor = 1.000000

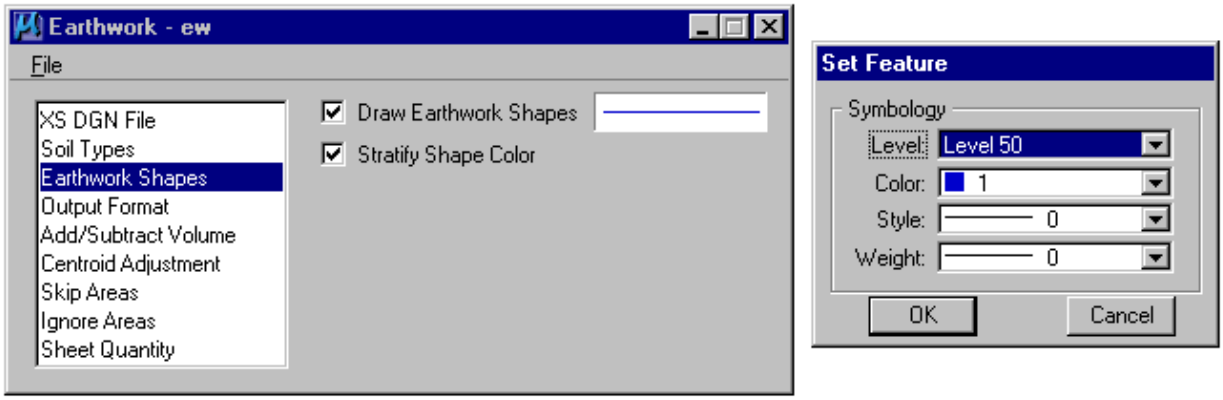
fill mult factor = 1.000000

type = line, line_string

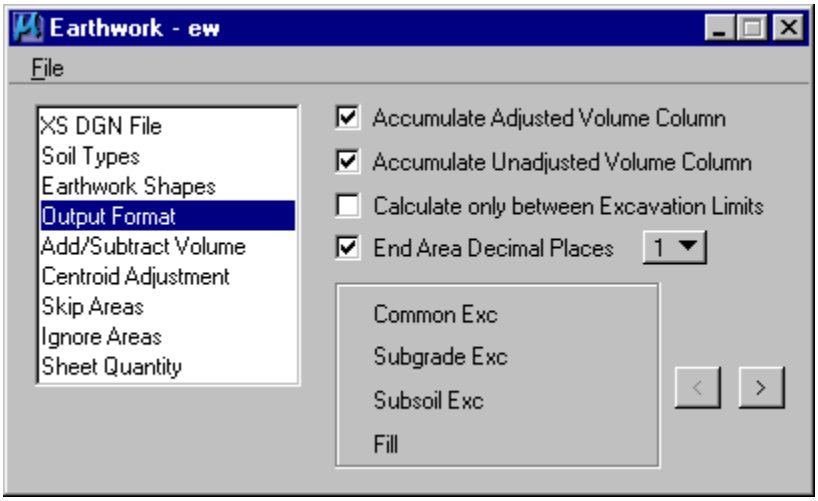
lv = 24-25,41,44-48,53



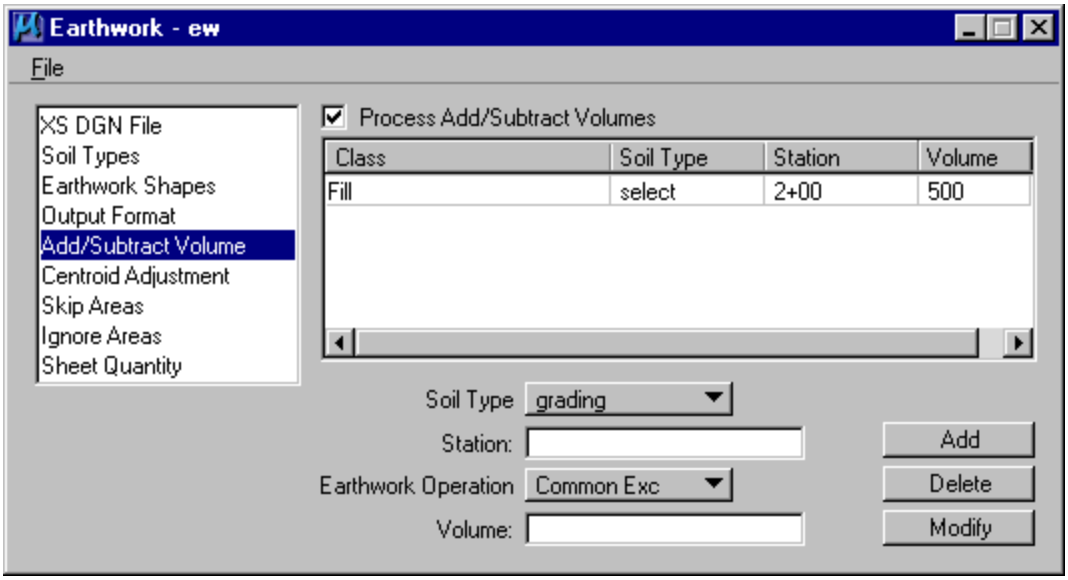
7. Next, select the **EW Shapes** option and set according to the dialog below.



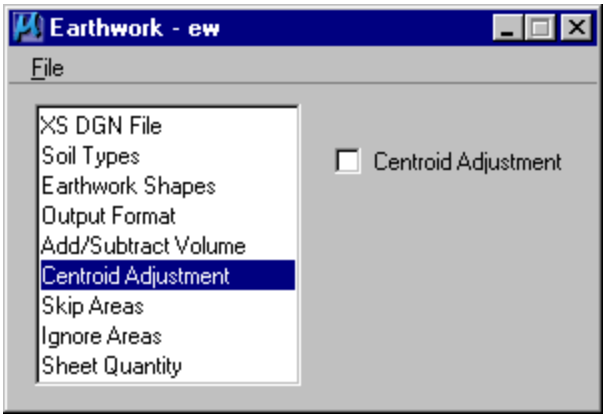

8. For the **Output Format** we will want to make sure to utilize the accumulative toggles as well as having the report display **Subgrade** and **Subsoil Excavations** as shown below.

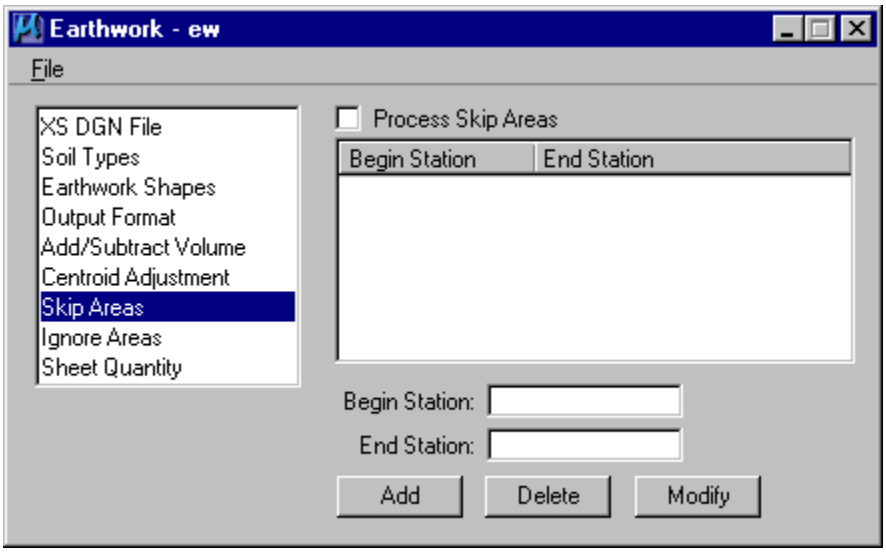


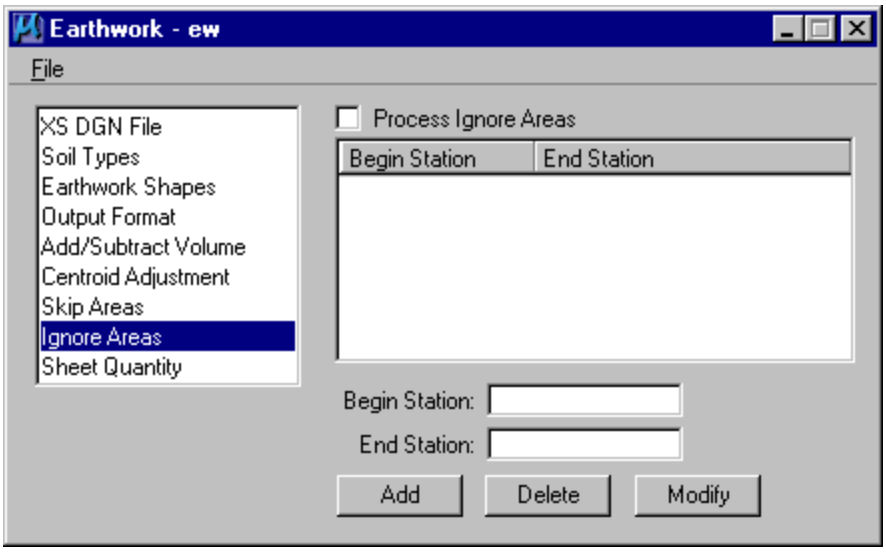

9. In the **Add/Subtract Volume** dialog, we will arbitrarily add 500 cubic yards of SELECT fill material. This will be displayed in the report at the given station.



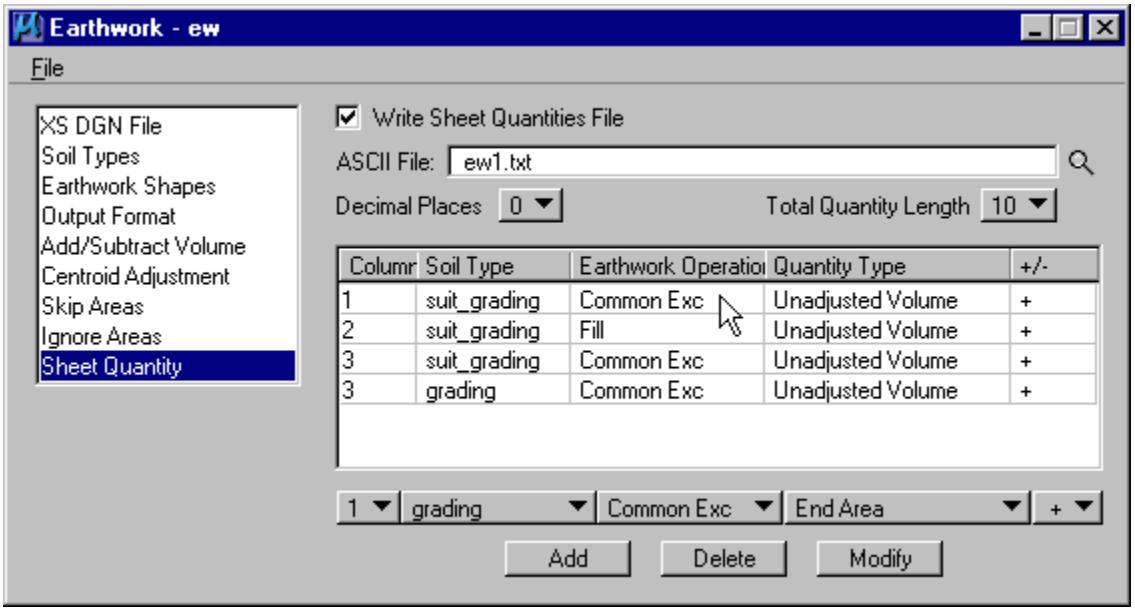

**10.** For this example the **Centroid Adjustment** the **Skip Areas** and the **Ignore Areas** will be avoided. So leave the dialog blank as shown below.





**11.** For the last option, **Sheet Quantities**, we will create a ASCII file for placing volumes onto the finished cross-section sheets. We will also provide a combined volume of **Grading** and **Suitable Grading**. Do this by populating the dialog as shown below.




**Note:** Notice that column 3 has 2 entries. This will facilitate the combining of the 2 soil types into a single volume.

column 1 formula = abs( ["SUIT_GRADING", Common Exc, Unadjusted Volumes] )

column 1 number of decimal place = 0

column 1 total length = 10

column 2 formula = abs( ["SUIT_GRADING", Fill, Unadjusted Volumes] )

column 2 number of decimal place = 0

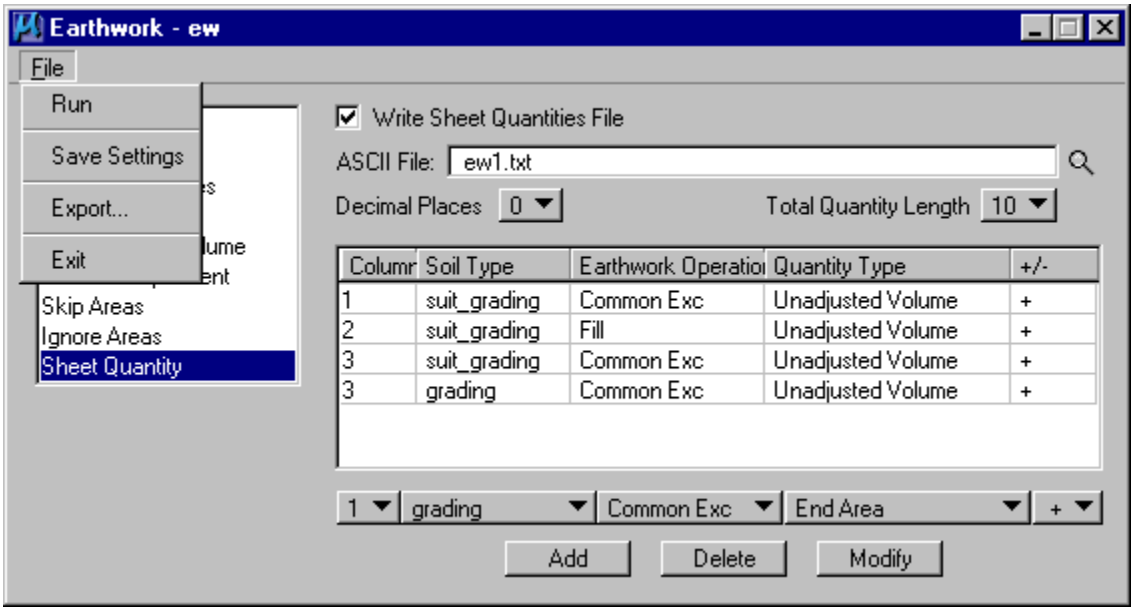
column 2 total length = 10

column 3 formula = abs( ["SUIT_GRADING", Common Exc, Unadjusted Volumes] + ["GRADING", Common Exc, Unadjusted Volumes] )

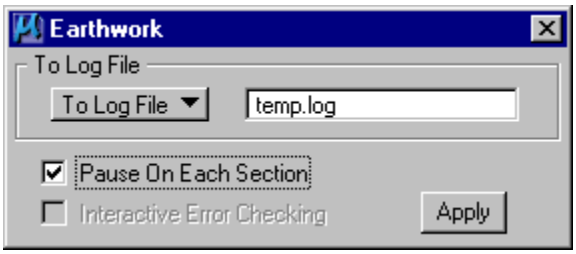
column 3 number of decimal place = 0

column 3 total length = 10

**12.** Once completed with all the dialog entries, return to the top of the dialog to the **File** pulldown and select **Save Settings**. Then from the same pulldown, select the **Run** option.




**13.** Be sure to supply a **Log File** name of your choice if you wish to have a printable format of the calculations.



**14.** The following is an example of the report you should receive.